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RELATING THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY TO MARINE JOB PERFORMANCE

by

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This thesis develops a method to reconfirm the relationship between an individual's Armed Services Vocational Aptitude Battery (ASVAB) scores and his performance at his initial course of instruction in the Marine Corps. Validity coefficients are developed to ensure that the ASVAB correctly predicts success at these initial training courses. Once the ASVAB is shown to correctly predict success at Marine Corps courses, the thesis concentrates on two statistical methods to explore the classification of youths into Marine jobs. The first method, discriminant analysis, is used as a check of the current classification process. Next, a tree based regression method is used to evaluate if further employment of ASVAB scores can more appropriately place trainees into Marine Corps jobs. These methods ultimately afford the Marine Corps an opportunity to use existing information to enhance the successful classification of young Marines into appropriate courses, thereby increasing their chances of successfully completing their initial training.

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RELATING THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY TO MARINE JOB PERFORMANCE

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ABSTRACT

This thesis develops a method to reconfirm the relationship between an individual's Armed Services Vocational Aptitude Battery (ASVAB) scores and his performance at his initial course of instruction in the Marine Corps. Validity coefficients are developed to ensure that the ASVAB correctly predicts success at these initial training courses. Once the ASVAB is shown to correctly predict success at Marine Corps courses, the thesis concentrates on two statistical methods to explore the classification of youths into Marine jobs. The first method, discriminant analysis, is used as a check of the current classification process. Next, a tree based regression method is used to evaluate if further employment of ASVAB scores can more appropriately place trainees into Marine Corps jobs. These methods ultimately afford the Marine Corps an opportunity to use existing information to enhance the successful classification of young Marines into appropriate courses, thereby increasing their chances of successfully completing their initial training.

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EXECUTIVE SUMMARY

The Armed Services Vocational Aptitude Battery (ASVAB) is the multiple aptitude battery used by the Marine Corps for the selection and classification of enlisted personnel. In the late 1970s, a normalization error in the ASVAB required all of the military services to conduct research to link aptitude requirements to military job performance. The ASVAB periodically requires the development of updated test batteries to ensure test effectiveness in the assignment of personnel. With these new iterations of the ASVAB, the relationship between the ASVAB and job performance must be reconfirmed, as the results affect decision makers in personnel, recruiting, and training commands throughout the Marine Corps.

This thesis is in support of an ongoing ASVAB validation study being conducted at the Center of Naval Analyses (CNA). The purpose of this thesis is to develop a method to link the relationship of Marine job performance to ASVAB scores. Additionally, the thesis explores statistical methods not previously used by CNA to promote understanding of how the ASVAB is used in classification of Marine recruits. Discriminant analysis is used as a check of the current classification process. A tree based method offers the Marine Corps graphical pictures to evaluate if further use of the ASVAB composites can more appropriately place trainees into their jobs.

The results of this project show that the ASVAB is a valuable tool in the selection and classification processes currently used in the Marine Corps. The continued use of the ASVAB is supported, as it is an appropriate battery to measure a youth's potential to

successfully complete the training course suited for that individual. The discriminant method shows that the ASVAB composites are placing individuals with similar aptitudes into courses requiring those types of individuals. The tree based method provides insight to an opportunity to improve on a course's average final grades. This increase in final grades implies that Marine job performance may likewise improve. These new methods promote further understanding of the ASVAB and its relationship with Marine job performance.

I. INTRODUCTION

The Armed Services Vocational Aptitude Battery (ASVAB) is the multiple aptitude battery used by the Marine Corps for the selection and classification of personnel. During the late 1970s, a normalization error within the ASVAB significantly overestimated military recruits' aptitudes. As a result, Mayberry and Carey (1993) observed "about one person in four accessed by the services would have been unqualified for service if the ASVAB had properly measured their aptitude." Congress questioned the impact of such low-aptitude personnel on the overall military effectiveness. Military manpower experts were unable to empirically quantify the degradation in actual job performance, however it was known that future effectiveness would suffer. Congress then mandated that each service conduct research to measure military job performance and to link aptitude requirements to these measures of performance (Mayberry and Carey, 1993). To that end, the Marine Corps requested that the Center for Naval Analyses (CNA) quantitatively illustrate the ASVAB's potential in measuring Marine job performance.

A 1985 CNA study shows that the ASVAB is a valid predictor of performance in Marine Corps occupational training courses, and the ASVAB should continue being used in personnel decisions regarding the selection of recruits and assigning them to occupational specialties (Maier and Truss, 1985). Since then, three additional studies, by CNA, have found a strong relationship between an individual's ASVAB scores and his job performance (Mayberry, 1990; Mayberry, 1991; Mayberry and Carey, 1993). Two of the studies involve infantry job performance, while the other focuses its attention on two

mechanical maintenance specialties: automotive and helicopter mechanics. All of the studies show that initial training school grades, the historical measure of job performance, are heavily influenced by an individual's ASVAB scores.

The ASVAB periodically requires the development of new test batteries to provide optimum test effectiveness in the allocation of personnel resources and to deter test compromise. Effective job classification results in cost reductions due to higher productivity, higher reenlistment rates, and reduced training school attrition (Palmer, Curran, and Haywood, 1990).

These results have considerable impact on military effectiveness and the types of individuals the Marine Corps should recruit in order to reduce attrition at entry level schools. Furthermore, the implication of the relationship between the ASVAB and job performance affects decision makers in personnel, recruiting, and training commands throughout the Marine Corps.

II. BACKGROUND

The Armed Services Vocational Aptitude Battery (ASVAB) is the multiple aptitude battery used by the Marine Corps for the selection and classification of personnel. The ASVAB consists of ten multiple choice subtests; their content, the number of items, and time limits are shown in the order of administration in Table 1. ASVAB subtests, like subtests of most multiple-aptitude batteries, are positively intercorrelated. Thus, the ASVAB subtests measure some general underlying cognitive attribute, as well as the specific abilities they were designed to measure (Welsh, Watson, and Ree, 1990).

The ASVAB is administered to applicants at military entrance processing stations. A military applicant's ASVAB subtest scores are then converted to standard scores with a mean of 50 and a standard deviation of 10. These standard scores are then used to calculate an individual's non-standardized composite scores, listed with their formulating equations in Table 2. The composites are then converted to standardized Marine Corps composites with a mean of 100 and a standard deviation of 20. These Marine Corps composites are used to assign the applicant to a job training course along with consideration of the individual's desires and the needs of the Marine Corps. Each recruit is selected for a job training course by scoring at or above the minimum ASVAB composite score for a particular course. Further, each job training course normally requires only one ASVAB composite score to meet the classification rule for that course.

Subtest	Content	Number of Items	Time (min) of Test
General Science (GS)	Knowledge of or about physical, chemical, and biological properties	25	11
Arithmetic Reasoning (AR)	Reasoning required to perform arithmetic processes	30	36
Word Knowledge (WK)	The meanings of selected words	35	11
Paragraph Comprehension (PC)	Understanding of written material from brief paragraphs	15	13
Numerical Operations (NO)	Knowledge of simple addition, subtraction, multiplication, and division	50	3
Coding Speed (CS)	Ability to identify and match similar sets of numbers and words	84	7
Auto and Shop Information (AS)	Knowledge of and familiarity with tools, shop practices, maintenance, and repair of automobiles	25	11
Mathematics Knowledge (MK)	Application of learned mathematics principles	25	24
Mechanical Comprehension (MC)	Understanding and application of various mechanical principles	25	19
Electronics Information (EI)	Identification or application of simple electrical or electronics knowledge	20	9

Table 1. ASVAB Subtest Descriptions. Subtests are presented in order of administration. Adapted from (Palmer, Curran, and Haywood, 1990).

Composite Name	Definition
Mechanical Maintenance (MM)	AR + EI + MC + AS
Clerical (CL)	VE + MK + CS
Electronics Repair (EL)	AR + MK + EI + GS
General Technical (GT)	VE + AR + MC

Table 2. Marine Corps ASVAB Composites. Verbal (VE) is the standardized sum of WK and PC subtests.

Maier and Truss (1985) created the current Marine Corps composites from forms 8, 9, and 10 of the ASVAB (ASVAB 8/9/10) through a stepwise analysis of regression weights. ASVAB 8/9/10 were first introduced in 1980. The ASVAB is periodically updated with new test batteries in order to provide optimum test effectiveness in the assignment of personnel. All forms since then are content and topologically equivalent to the reference ASVAB form 8a (Ree and Earles, 1992). No further discussion of the different ASVAB forms is warranted for the purpose of this thesis.

This thesis is in support of an ongoing ASVAB validation study being conducted by Paul Mayberry at the Center for Naval Analyses (CNA). Every updated iteration of the ASVAB leads to its own battery of research to ensure that all quality control measures and job predictive nature remains intact. CNA has collected a substantial data set to conduct their validation research on behalf of the Marine Corps. The data set is a comprehensive merger of three years of students' records from a vast majority of initial Marine training courses and their associated Defense Manpower Data Center records. Each record represents one individual and includes their ASVAB subtest and composite scores along with their final course grade (FCG) earned at their initial training course.

A. PROBLEM STATEMENT

The purpose of this thesis is to develop a method to reconfirm the relationship between an individual's ASVAB scores and his performance at his initial course of instruction. The Marine Corps continues to request that CNA solve this complex problem of classifying youths into Marine jobs. (Maier & Truss, 1985; Mayberry, forthcoming)

This thesis explores statistical methods not previously used by CNA to promote further understanding of how the ASVAB is useful in the classification of youths.

First, a predictive validity coefficient for the ASVAB will be developed. This coefficient will ensure that the ASVAB accurately predicts an individual's ability to successfully complete the particular training course for which they have been assigned. Once the validity of ASVAB subtest scores used in predicting success at initial training courses has been verified, the thesis will concentrate on statistical methods to determine if individuals can be classified solely on their ASVAB composite scores. Discriminant analysis is used as a check of the current classification process. This method further affords an opportunity to investigate whether the ASVAB is properly placing individuals into military occupational specialties (MOSs) with a large chance of success. A tree based method offers the Marine Corps graphical pictures, by course, to see if further use of the ASVAB composites can more appropriately place trainees into their MOSs. Finally, both techniques promote increased understanding of the relationship between Marine job performance and the ASVAB, along with how this relationship is used in the classification process.

B. DATA

The data set for this thesis was collected by CNA. Prior to data extraction for this thesis, CNA conducted an initial screen for obvious key punch errors. The courses considered for this project were limited to a 1995 annual projected throughput of at least 200 Marines. This list of 54 courses is included in Appendix A.

From this course list, eight were selected for examination. These eight courses were selected to balance the four Marine Corps composites, i.e., each composite is allocated two courses. One course is above the mean composite score of 100 and the other is at or below 100. This method of selecting courses provides insight into both the ASVAB's predictive and differential potentials. The courses, selection criteria, and sample size are shown in Table 3.

Course Title	Selection Criteria	Sample Size
Rifleman (Lejeune)	GT $\geq$ 80	3144
Field Artillery Fire Controlman	GT $\geq$ 110	291
Field Radio Operator	EL $\geq$ 90	1103
Basic Electronics	EL $\geq$ 115	388
Unit Diary Clerk	CL $\geq$ 100	686
Communications Center Operator	CL $\geq$ 110	676
Basic Hygiene Equipment Operator	MM $\geq$ 85	483
Aviation Machinist Mate	MM $\geq$ 105	543

Table 3. The eight courses along with their selection criteria and number of samples.

For each individual, the data set includes all of their subtest scores, their Marine Corps composites, final course grade (FCG), an attrition variable, a completion code, date of entry into the service, and the date of course completion. The first three are discussed in separate sections. The date of entry into the service and the date of course completion are used to determine if an individual is on his initial attempt at his first training course. Before the completion and attrition codes are introduced, a discussion of the criterion measure, FCG, is necessary.

1. Criterion Measure

Final course grades (FCGs) of trainees in Marine Corps occupational training courses are used as the criterion measure to determine the predictive validity coefficient of the ASVAB. In most Marine Corps courses, FCGs are reported as percentage scores where the minimum passing grade is 70 and the maximum score is 100. Table 4 shows some descriptive statistics associated with the eight courses of interest.

Final Course Grade (FCG)

Course Title	Sample Mean	Std Dev	Min	Max
Rifleman (Lejeune)	88.6	5.6	64.4	100.0
Field Artillery Fire Controlman	89.2	5.8	71.1	99.4
Field Radio Operator	89.8	6.9	63.5	100.0
Basic Electronics	77.8	9.9	63.4	96.0
Unit Diary Clerk	92.9	4.0	82.7	100.0
Communications Center Operator	89.2	6.0	64.0	100.0
Basic Hygiene Equipment Operator	93.8	3.2	79.3	100.0
Aviation Machinist Mate	86.1	5.7	64.4	99.3

Table 4. For each course, descriptive statistics of the Final Course Grades (FCGs) are shown.

From previous studies (Maier & Truss, 1985; Mayberry, 1990), a lack of variability in FCG has been identified as a measurement problem. This problem comes about because some Marine courses train students to perform selected job tasks and then test students until they master those skills. This method of instruction heavily favors training and reduces the variability of FCGs given to the students. This instructional technique accomplishes its purpose of producing Marines with known capabilities.

However, from a statistical perspective, the tight distribution of FCGs does not always afford much interpretation of job performance as nearly everyone receives the same grade. This development may lead to the need of a different criterion measure in order to validate the ASVAB and, equally troublesome, to solve the recruit classification problem.

In order to establish FCG data manipulation rules, the completion code works with the attrition variable as shown in Table 5. This combination of data allows for some insight as to how an individual completed the course and further helps establish rules in using a particular individual's record of relating initial training performance to the ASVAB.

If ATTRITE = 0 (a graduate) then
COMPLETION CODE = 1 is a regular pass
COMPLETION CODE = 2 is an academic recycle
COMPLETION CODE = 3 is a non-academic recycle
If ATTRITE = 1 (attrited from course) then
COMPLETION CODE = 1 is an academic attrite
COMPLETION CODE = 2 is a non-academic attrite

Table 5. Defining the attrition and completion codes contained within the data set.

For example, if an individual passes the course (attrition = 0), but not on his first attempt (completion code = 2) his FCG is changed to reflect a minimum passing grade. Alternatively, if a trainee fails the course (attrition = 1), but the failure is for non-academic reasons (completion code = 2) his FCG, if given, is used as if he had passed. If a trainee fails the course for academic reasons (attrition = 1; completion code = 1) and his FCG is less than one standard deviation from the minimum passing grade, the individual's FCG is increased to that measure. Otherwise, his FCG is taken as is.

2. ASVAB Subtests and Composites

Individuals with missing ASVAB scores were eliminated from consideration. Table 6 shows, by course, some descriptive statistics of the ASVAB subtests and composites.

ASVAB Scores

	Sample	Subtests											Composites			
Course Title		GS	AR	WK	PC	NO	CS	AS	MK	MC	EI	VE	GT	CL	MM	EL
Rifleman	μ	53.2	52.3	53.1	53.5	53.4	52.1	51.6	53.6	54.1	51.0	53.4	107.5	107.2	105	105.8
(Lejeune)	σ	7.4	7.1	4.9	5.4	6.9	6.6	7.7	7.4	7.7	7.6	4.6	11.8	10.4	13.0	12.7
	min	33	27	30	22	20	24	29	33	27	27	33	80	75	70	74
	max	69	66	61	61	63	72	69	68	70	70	62	136	138	139	140
Field Artillery	μ	56.8	57.5	55.9	55.7	54.7	53.1	54.0	57.6	60.6	54.6	56.1	118.3	113.2	115.3	115.1
Fire Controlman	σ	5.9	5.6	3.5	4.0	6.3	6.1	7.4	6.7	5.1	7.0	3.2	7.1	8.5	10.0	10.1
	min	42	41	44	42	32	32	25	34	47	22	46	101	91	89	92
	max	69	66	61	61	63	71	69	68	70	70	62	135	134	141	138
Field Radio	μ	52.3	51.4	51.7	52.1	53.8	51.6	48.6	54.1	50.9	50.1	51.9	103.2	106.0	100.6	104.6
Operator	σ	6.5	6.8	5.3	5.9	6.7	6.9	7.8	6.8	8.1	6.9	5.0	12.0	10.2	12.7	10.7
	min	32	35	33	21	29	22	29	35	32	31	34	78	77	74	87
	max	69	66	61	61	63	72	69	68	70	69	62	134	135	140	139
Basic	μ	59.1	59.5	56.2	55.8	56.3	54.1	54.6	61.7	59.6	58.2	56.3	119.3	117.3	118.2	121.9
Electronics	σ	5.0	4.9	3.6	4.2	5.8	7.0	7.4	4.6	6.6	6.0	3.4	8.0	8.2	9.5	6.5
	min	41	40	42	39	33	30	35	47	40	41	42	89	91	91	100
	max	69	66	61	61	63	72	69	68	70	70	62	136	138	141	140
Unit Diary	μ	50.7	51.0	52.2	53.0	56.5	55.4	47.4	55.3	50.9	48.3	52.6	103.4	110.4	98.6	103.1
Clerk	σ	7.2	7.3	5.0	5.3	5.4	6.1	7.6	6.1	8.0	7.6	4.5	11.9	7.5	13.3	11.8
	min	27	34	27	33	28	28	31	38	30	25	32	80	91	66	75
	max	67	66	61	61	63	72	68	68	69	69	62	134	134	136	136
Communications	μ	53.8	54.4	54.6	55.3	57.1	57.7	49.1	58.9	54.1	50.7	55.0	110.2	116.9	104.7	110.1
Center Operator	σ	6.9	6.8	4.4	4.4	5.5	6.1	7.4	5.2	7.7	7.4	4.1	11.1	6.2	12.7	11.0
	min	31	35	40	34	21	30	29	43	35	33	40	83	95	75	80
	max	69	66	61	61	63	72	69	68	70	70	62	136	138	137	140
Basic Hygiene	μ	51.8	52.6	51.7	51.9	52.8	51.7	54.0	53.5	55.2	52.9	51.9	107.3	105.6	108.4	106.2
Equipment	σ	6.9	6.7	5.3	5.8	7.0	6.6	7.8	7.3	7.1	6.7	4.9	10.8	10.1	11.8	11.5
Operator	min	30	35	23	31	20	29	33	35	35	33	28	74	75	83	80
	max	67	66	61	61	63	72	69	68	69	69	62	132	136	135	135
Aviation	μ	56.0	55.9	54.4	54.6	54.8	53.4	56.2	57.2	59.2	55.7	54.7	114.9	112.0	115.4	114.1
Machinist Mate	σ	6.2	5.8	4.4	4.8	6.4	6.6	6.6	6.7	5.3	5.9	4.1	8.1	9.4	8.3	9.4
	min	35	33	35	30	20	23	34	37	44	36	38	89	84	84	87
	max	69	66	61	61	63	72	69	68	70	70	62	136	134	141	138

Table 6. For each course, descriptive statistics of the ASVAB scores are given. Listed beside each course: the first line represents the sample mean of each score; the second, the sample standard deviation; the third, the minimum; and finally, the maximum.

C. THESIS ORGANIZATION

The motivation of validity coefficients, discriminant analysis, and tree based regression methods is contained within Chapter III. Chapter IV gives the results of the predictive validity of the ASVAB scores, and the results of discriminant and tree based methods that provide further insight into the classification of young Marines. Finally, Chapter V provides conclusions and recommendations for possible future research.

III. METHODOLOGY

The methodology for this thesis is presented in three main sections. The first section contains a discussion of validity coefficients currently used to show the link between job performance and the ASVAB. The second section presents the discriminant analysis method used to identify groups by their ASVAB scores. Finally, the third section discusses a tree based regression method to evaluate if further employment of the ASVAB composites might result in higher average FCGs for the Marine Corps training courses. All of these sections promote understanding of the ASVAB and its relationship with Marine job performance.

A. VALIDITY COEFFICIENTS

Validation coefficients are correlations used to assign a value to the predictive power of the ASVAB and its ability to successfully forecast performance in a particular course. The validation coefficients assess the validity of the ASVAB examination subtests by showing that they accurately predict how well trainees will do in military job courses. Nunnally (1978) argues that even a moderate correlation (e.g., a correlation of 0.30) between test and criterion can prove quite useful for selection purposes. He explains that the "proper way to interpret a validity coefficient is in terms of the extent to which it indicates a *possible improvement in the average quality of persons* that would be obtained by employing the instrument in question."

The validity of a test is the correlation of the test with some criterion. The study of validity coefficients for a given test has shown that they vary by school and date of the

test. In other words, validity cannot be regarded as a fixed characteristic of a test. A validity coefficient is defined as the correlation of a test (ASVAB) to the criterion measure (FCG). Many validity coefficients can be created for each school through different combinations of the ASVAB subtests scores.

1. Types of Selection

There are two types of selection: explicit and indirect. Explicit selection occurs when individuals who score above a critical score on an aptitude test are admitted and those below it are rejected. This type of selection directly affects the population included in a particular course. An indirect selection effect occurs when one variable is brought about by explicit selection of another correlated variable. For example, college aptitude tests help schools explicitly select individuals to attend. Individual performances, while at college, are indirectly affected by this explicit selection process. It is important to distinguish between these types of selection in order to capture the actual validity of the aptitude test.

An example is seen using the explicit selection of Marines into the Basic Electronics course. A proportion of Marines with a 115 or greater EL composite score are selected into the course. Therefore, the criterion measure of FCG is affected indirectly by their explicit selection into the Basic Electronics course. In order to correct for the results of selection, it becomes necessary to use an index that is not affected by the selection process. Such an index could be the error estimate from a reference population.

The actual selection procedures are usually complex and clouded. Special considerations are usually given to prior work related to the course work, a high school

degree, or other such verifiable individual differences. These exceptions to rigid procedures often obscure the acceptance process. This necessitates that reasonable assumptions be made regarding the selection procedure operating on our particular case. In practice there are numerous extenuating circumstances that may override the strict selection rules. For the purposes of this thesis, Marine Corps Order P1200.7 Military Occupational Specialties Manual is the authority of selection rules.

2. The Effect of Group Heterogeneity on Validity

The ideal validation study would administer a number of selection tests to an entire group. Then the entire group, without pre-selection, would be admitted to the training course and be given the criterion measure under identical conditions. Under these situations, the necessity of correcting for homogeneity is completed avoided. The different selection tests may then be compared directly. This thesis is concerned with creating validity coefficients with two variables; one used for explicit selection (ASVAB subtests) and the other indirect selection (FCG) given at the completion of the course.

The heterogeneity of the group tested will affect the validity coefficient. Because lower aptitude persons are removed from consideration for courses, the validity coefficient of the entire population of youths would be greater than the validity coefficient of the restricted group. The restricted group is defined as those individuals that take the ASVAB and complete a specific course. By way of a two dimensional example, Figure 1 shows a contour ellipse of constant values for the joint density of ASVAB scores and FCG scores. By restricting individuals admitted into courses by their ASVAB scores, the population validity coefficient is underestimated. The population validity coefficient is

then defined as the correlation of the entire ellipse. Those individuals removed by the selection process are represented by the unshaded region, which can be created with estimated ASVAB scores and the FCGs for those individuals. The shaded portion of the ellipse represents those individuals for which data has been collected.

The sample validity coefficient that is found from the data is indicated using the shaded portion of the ellipse in Figure 1. Such screening of potentially unsuccessful applicants reduces the validity coefficient and a correction for range is appropriate. The corrected validity coefficient, R_{XY}, is computed through the following equation (Gulliksen, 1950):

$$R_{XY} = \sqrt{1-\left(1-r_{xy}^2\right)\frac{s_y^2}{S_Y^2}},$$

where x is the sample explicit variable from the selected group,
y is the sample indirect variable from the selected group,
X is the corrected for range restriction explicit variable,
Y is the corrected for range restriction indirect variable,
r_{xy} is the sample correlation between x and y,
s_y^2 is the variance of sample y,
S_Y^2 is the variance of reference population Y.

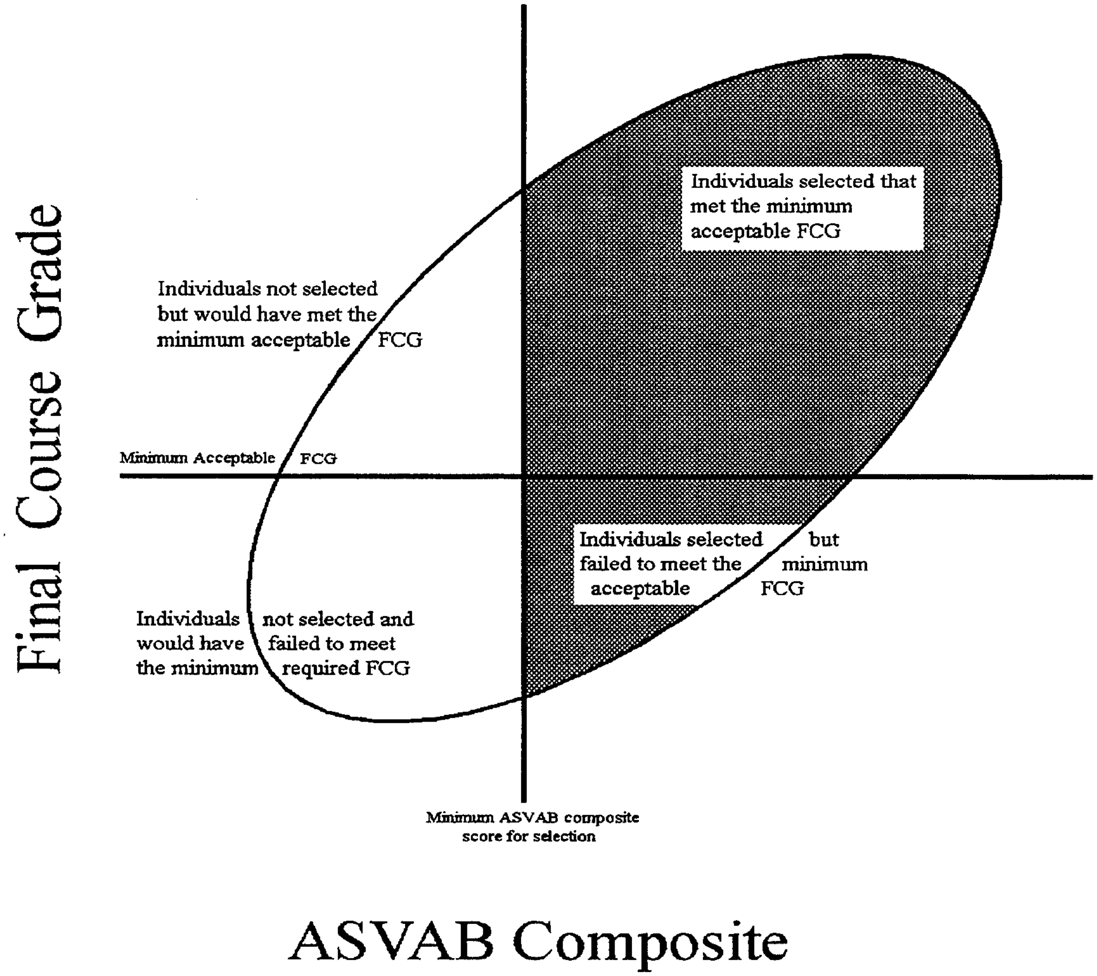

Figure 1. An illustration of the change in correlation with selection. The shaded portion is the area for which we have data and can collect a sample validity coefficient between an ASVAB composite and FCG.

If a course is more difficult to qualify for, then intuitively the shaded portion of the ellipse decreases. As the ellipse captures less of the youth population, the validity coefficient corrected for range restriction is increasingly important to the understanding of the predictive power of the ASVAB.

3. Classification Dilemma

Figure 1 also provides insight to the classification dilemma. The dilemma is to increase the number of students that successfully complete the course, while simultaneously rejecting those students who do not have the aptitude required to complete the course. These conditions must be balanced with consideration to the remaining individuals whose true ability is falsely perceived by the aptitude test. Both directions are of concern. The ASVAB can understate an individual's true ability as well as inflate another's ability.

If the minimum ASVAB composite threshold is set too low, many unqualified Marines would be accepted to the course. Subsequently, job performance would decrease on average, given that roughly the same proportion of students passed the course. This situation creates a large expense in terms of both morale and actual dollars. Conversely, many Marines with the skills necessary to pass the course would not be given a chance to attend, if the critical ASVAB threshold is set too high. Further, this condition may result in a shortage of Marines in certain MOSs because there would not be enough qualified candidates to fill these courses.

B. DISCRIMINANT ANALYSIS

Linear multiple discriminant analysis is used to distinguish the membership of individuals in a number of known groups. R. A. Fisher (1936) developed this method with Anderson's iris data. By taking four measurements of the flowers, three varieties of iris can be classified quite accurately with Fisher's linear discriminant model. This success is due largely to the fact that the measurement variables used are excellent discriminators.

For the purpose of this thesis, the students' ASVAB subtest scores are used to classify them into courses. For each individual, the linear discriminant function creates a score for every course. Presumably, an individual is then assigned to the course for which his discriminant score is highest.

It is important to understand that an individual's best score points him to a particular course, but this assignment does not necessarily mean that he could not succeed in other courses. Discriminant analysis attempts to use ASVAB subtest scores in order to separate groups of individuals. In the case of similar courses, such as the Communications Center Operator course and the Unit Diary Clerk course, it may be that discriminant scores are high for both and clear differences cannot be discerned between them. We allow the assignment of individuals to either one of these courses.

An often useful measure associated with discriminant analysis is the misclassification rate between pairs of groups. This measures the rate at which individuals are assigned to one group, when in fact they belong in another. This usage is neither the intention nor the focus of this thesis. Many individuals could be grouped into a wide assortment of Marine courses and would likely achieve a satisfactory FCG in those courses. Therefore misclassification is inappropriate terminology for this thesis. The operational classification system utilizes both the knowledge of an individual's preferences and the Marine Corps' need to place a planned number of students into each course.

The usefulness of discriminant analysis in our application is to illustrate that distinct groups of individuals can qualify for many schools and such qualification is identified. The ASVAB composites were designed with much overlap and they capture

this phenomena. Our scores serve to identify these groups. The discriminant method assigns a score for each course given an individual's set of ASVAB subtest scores. From these discriminant scores, an individual's highest score is chosen. This score identifies an individual's discriminant course.

C. Radhahrishna Rao (1965) gives an excellent discussion of the discriminant procedure. The computational method follows: for each individual j, a set of linear discriminant scores, S_i^j, for each course i is calculated as:

$$S_i^j = (\mu_i^T \Sigma^{-1}) U_i^j - \frac{1}{2}\left(\mu_i^T \Sigma^{-1} \mu_i\right) + \log(\pi_i) \qquad \forall i$$

where i = total number of courses considered
j = an individual
μ_i = vector of mean predictor values
Σ^{-1} = inverse of the dispersion matrix
U_i^j = vector of an individual's predictor values
π_i = percentage of individuals assigned to course i

More elaborate discriminant scoring functions can be created and could be more useful in setting qualification thresholds for Marine courses. These functions might include knowledge of the Marine Corps' need to place a certain number of students into a particular course. Or the recruit's preference for courses could be given weight in a new discriminant function.

C. TREE BASED MODEL

The use of tree-based models is a recent and attractive aid in decision making processes. For instance, the medical field uses tree based methods to provide a way to encapsulate and structure expert knowledge for use by less experienced users. The tree

based model, for this thesis, examines each school individually in an attempt to further understand the classification of trainees.

Most Marine schools use only one ASVAB composite for job classification. Our tree based model uses all four Marine composites to show that furthering the selection criteria will enhance the average criterion measure, FCG, for each course. This correctly implies that the higher the FCG the better. It uses the ASVAB composites to their fullest extent. The pictorial display of information is easily reproduced and works much like a flow chart for assignment purposes.

Each course is considered individually. Trainees with the higher FCGs can be identified by splits in the tree structure using the four Marine composites. It is quite possible to grow a tree that over-fits the data set when the data's distributions overlap, resulting in an overly elaborate tree. The established methodology for recovering from this over-fitting of the data set is the tree pruning procedure.

As a tree grows to fit the data set, it can over-fit to the particularities within the data set. By identifying these over-fit leaves, a tree pruning method will clip off these over-fit leaves allowing for a more parsimonious tree that more accurately portrays the entire population or future populations.

The method used within this thesis divides each course's data set into ten roughly, equally sized data sets. Nine of these are used to grow the tree, and the tenth is used to test the tree structure. This testing procedure creates a tree size versus deviance plot. As the tree size grows, the deviance is lowered. At some point, the tree structure created by the nine data sets becomes too specific. So after this point, as the size of the tree

continues to grow, the deviance of the test data set begins to increase. This procedure can be done in ten different ways by changing the test data set. As seen in Figure 2, the average deviance from these trees can be found and plotted to find the smallest tree structure with the least amount of deviance.[1] From this plot, the tree size is chosen and a final tree is created from a course's complete data set. This final tree structure is referred to as a course's most parsimonious tree.

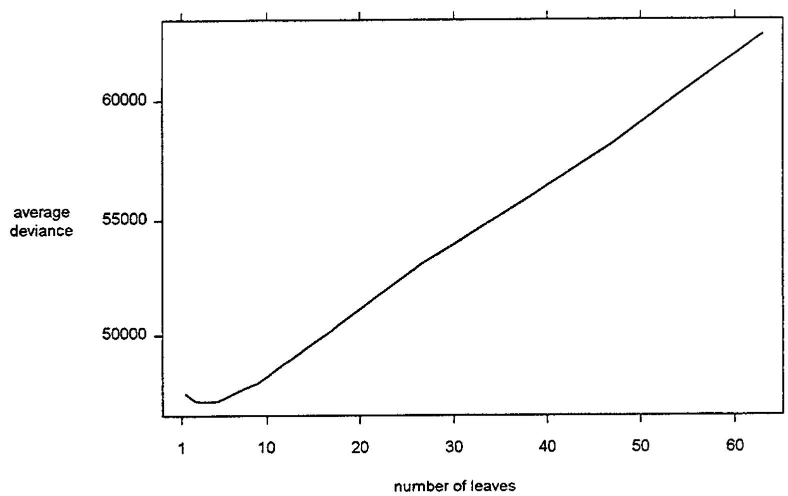

Figure 2. Average deviance of the ten tree models versus the size (number of leaves) of those tree structures.

1 The deviance (D), as defined by S-Plus for their regression tree model, is as follows:

$$D = \sum_{\text{cases } j} \left(y_j - \mu_{[j]}\right)^2$$

The deviance is the sum over the leaves of D_i, the corrected sum of squares for cases with that node, and the value of a split is the reduction in the residual sum of squares. The tree construction process is seen as a hierarchical refinement of probability models, very similar to the forward variable selection in regression models (Venables and Ripley, 1994).

IV. RESULTS OF THE ANALYSIS

The results of the analysis are presented in three main sections. In the first section, validity coefficients that support the continued use of the ASVAB for selecting and assigning Marine recruits are presented. The second section presents the discriminant identification of groups comprised of similar individuals based upon their aptitude ASVAB subtest scores. Finally, the third section shows that further use of the ASVAB composites through a tree based method may lead to a higher FCG overall for each course.

A. PREDICTIVE VALIDITY OF THE ASVAB

The predictive validity of the ASVAB is based on the eight courses discussed previously in Chapter II. The sample validity values are shown in Part I of Table 7. These values are distorted because the Marine recruits had been selected to these courses on the basis of their ASVAB scores. These effects on the validity coefficients were removed by applying the correction for range restriction explained in Chapter II. The corrected values, called the population coefficients, are shown in Part II of Table 7. These validity coefficients are comparable to those in an earlier ASVAB validation study (Maier and Truss, 1985) using the ASVAB 8/9/10 to predict training grades in Marine Corps initial job courses.

Part I. Sample Validity Coefficients

Course Title	ASVAB Subtests GS	AR	NO	CS	AS	MK	MC	EI	VE
Rifleman (Lejeune)	0.13	0.11	0.04	0.06	0.09	0.14	0.14	0.11	0.11
Field Artillery Fire Controlman	0.23	0.42	0.17	0.23	0.04	0.48	0.06	0.12	0.08
Field Radio Operator	0.25	0.30	0.11	0.18	0.19	0.34	0.33	0.17	0.29
Basic Electronics	0.11	0.20	0.12	0.16	0.16	0.29	0.18	0.13	0.16
Unit Diary Clerk	0.21	0.38	0.08	0.13	0.20	0.34	0.30	0.28	0.20
Communications Center Operator	0.28	0.34	0.03	-0.04	0.13	0.29	0.22	0.16	0.29
Basic Hygiene Equipment Operator	0.21	0.19	0.10	0.16	0.17	0.23	0.21	0.16	0.16
Aviation Machinist Mate	0.20	0.31	0.17	0.24	0.15	0.27	0.18	0.23	0.28

Part II. Estimated Population Validity Coefficients

Course Title	ASVAB Subtests GS	AR	NO	CS	AS	MK	MC	EI	VE
Rifleman (Lejeune)	0.18	0.17	0.13	0.13	0.15	0.18	0.18	0.16	0.17
Field Artillery Fire Controlman	0.41	0.52	0.38	0.40	0.34	0.57	0.35	0.36	0.35
Field Radio Operator	0.49	0.51	0.45	0.46	0.47	0.53	0.52	0.46	0.51
Basic Electronics	0.63	0.64	0.63	0.64	0.64	0.67	0.64	0.63	0.64
Unit Diary Clerk	0.61	0.67	0.59	0.60	0.61	0.65	0.64	0.63	0.61
Communications Center Operator	0.66	0.68	0.63	0.63	0.63	0.67	0.65	0.64	0.66
Basic Hygiene Equipment Operator	0.44	0.44	0.41	0.43	0.43	0.45	0.44	0.43	0.43
Aviation Machinist Mate	0.73	0.74	0.72	0.73	0.72	0.74	0.72	0.73	0.74

Table 7. Sample and Estimated Population Validity Coefficients.

All of the population coefficients are positive. This is not surprising since the ASVAB subtests are included on the basis of their validity and reliability. More importantly, the result indicates that all ASVAB subtests have predictive validity for the

eight Marine Corps training courses of interest. To be useful for selection and assignment purposes, the population validity coefficients should have two properties: First, they should have moderate estimated values, and with the exception of the rifleman course they do. Second, they should have differential validity, which means each of the ASVAB's subtest population coefficients should have different values.

B. DISCRIMINANT METHOD RESULTS

A discriminant analysis method is used to group similar individuals by their ASVAB subtest scores into Marine training courses. This is done in order to find the course for which they have a large likelihood of successful completion. Again the eight courses are used, but only Marines who successfully complete the courses are considered. The results of the discriminant method are shown in Table 8 in a matrix format.

	Rifleman (Lejeune)	Field Artillery Fire Controlman	Field Radio Operator	Basic Electronics	Unit Diary Clerk	Communications Center Operator	Basic Hygiene Equipment Operator	Aviation Machinist Mate
Rifleman (Lejeune)	66	26	22	33	2	19	27	5
Field Artillery Fire Controlman	13	79	20	24	0	42	9	13
Field Radio Operator	0	0	89	5	28	16	28	34
Basic Electronics	12	37	19	58	0	24	24	26
Unit Diary Clerk	15	7	26	16	111	25	0	0
Communications Center Operator	12	27	1	42	57	61	0	0
Basic Hygiene Equipment Operator	14	19	40	15	0	0	85	27
Aviation Machinist Mate	28	18	8	28	0	0	14	104

Table 8. Discriminant Matrix for the eight courses. By row, 200 individuals are originally assigned to a course. The individuals are then assigned to columns by discriminant scores.

The rows in Table 8 represent the courses for which individuals were originally assigned to by their ASVAB composite scores. A random sample of 200 successful trainees from each course was taken for the purposes of this thesis. The columns represent the discriminant assignment of individuals to one of the eight courses. The

shaded diagonal represents those individuals originally assigned to a course and then grouped into that same course by discriminant scores. Interestingly, there appears to be a number of distinct types of individuals identified by this method. That is to say, given an individual's ASVAB subtest scores, he can be placed into a suitable course.

An example of this grouping is seen in the Unit Diary course. Of the 200 originally assigned, 111 are assigned to this course by their discriminant scores. Additionally, 25 of those originally assigned to the Unit Diary course were assigned to the Communications Center Operator's course by their discriminant score. These individuals are also more suited towards clerical related work. Of the original 200 assigned to the Unit Diary course, more than 65% are assigned to courses that require individuals to have an aptitude towards clerical related tasks.

Other trends can be seen in Table 8. Individuals originally assigned to more difficult courses, defined as courses requiring ASVAB composite scores greater than 100, are more likely to be placed by their discriminant scores into other comparable courses. The reverse of this trend is also observed. Those originally assigned to easier courses tend to be placed by the discriminant method into easier courses. This result is intuitive in that the ASVAB is designed to measure a general ability as well as specific aptitude qualities.

Another result is that the largest number of individuals assigned to a course by the discriminant method is the same course that those individuals were originally assigned to by the ASVAB composites. These courses are approximately twice as large as the next course assigned by the discriminant method, with the only exception being the Communication Center Operator's course. Finally, the zero entries in Table 6 serve to

identify pairs of courses that have poor interchangeability in the discriminant assignment procedure.

C. TREE BASED METHOD RESULTS

The purpose of the tree based analysis is to see if further use of the ASVAB composites will lead to an increase in the mean FCG for a particular course. In Figure 3, each course's parsimonious tree shows an opportunity to improve on average its FCG. This implies that Marine job performance may likewise improve. All the course's FCG distributions were standardized with a mean of 50 and standard deviation of 10. Importantly, all eight trees are simple (3 to 5 leaves) which suggests that the current selection process is doing well and that only minor adjustments are needed to show improvement in the criterion measure of job performance.

A detailed look at the Field Artillery Fire Controlman course's tree shows that it has two splits and three leaves. The first split makes use of the CL composite: The left branch shows that 135 individuals have a CL score that is less than or equal to 112 and an average FCG of 45.59; The right branch is made of those individuals that have a CL score greater than 112. These individuals are further separated by splitting on the EL composite, which creates the final two leaves. Then 102 individuals will have an EL composite score that is less than or equal to 123 and their average FCG is 51.84. Finally, 54 individuals have an EL composite greater than 123 and their average FCG is 57.54, which is significantly larger than the mean course grade of 50. If the Marine Corps only needed 50 artillery fire controlman, then this tree may afford a graphical aid to that selection process.

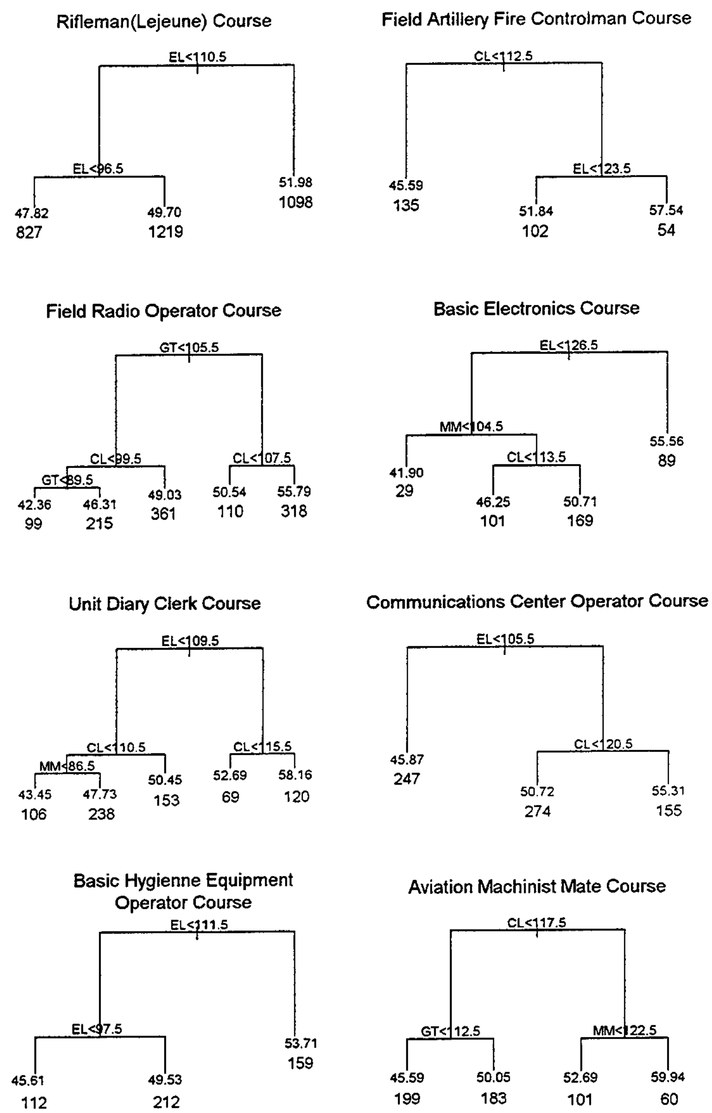

Figure 3. By course, their resultant course trees. At each leaf, two numbers are listed: the average FCG and the number of individuals that comprise the terminal node.

The tree based analysis shows that every split on an ASVAB composite identifies individuals with the higher scores and they tend, on average, to perform better in every course. This result is telling, and suggests that as individuals score higher on the ASVAB they are more likely to outperform individuals that score lower on the ASVAB. Additionally, this result does not penalize individuals for having composite scores that are

too large when the selection process is used for assigning individuals. The regression trees provide quantitative information confirming that individuals with higher ASVAB aptitude composites, regardless of which course, will on average outperform students with lower ASVAB scores.

Five out of eight courses use the EL composite for its tree's first split. This result shows that the EL composite contains some of the greatest differences among individuals. Additionally, many of the courses use a different composite to further differentiate individual's FCGs from the composite originally used to select those same individuals in a particular course.

This method affords a means to quickly identify trends within a course. For example, in the Basic Electronics course 89 of the 388 total Marines selected to attend the school have an EL composite greater than 126. These initial trainees are more likely to outperform individuals with EL composites less than 126 as measured by the significantly larger average FCG.

These results can only be used for trending purposes, since the allocation needs of the Marine Corps and the preferences of the future pool of recruits are absent, and beyond the scope of this project. An application of these trees to the selection process without regard to required manpower and throughput issues would be a disservice to both the Marine Corps and the potential Marine recruits.

V. CONCLUSIONS AND RECOMMENDATIONS

The ASVAB is a valuable tool in the selection and classification processes currently used in the Marine Corps. The collection of recruits' aptitude scores is a statistical information base that can be useful since quantifiable differences exist. The purpose of this thesis was to apply new methods to this data base with the hope these procedures would aid decision makers.

Careful consideration must be given to the importance of FCGs produced at the Marine Corps training courses. Some of these courses lack variability in their distribution of FCGs. If more Marine Corps courses assign the same grade to each student, future creation of ASVAB composites will have to be done with more expensive and time consuming measurements such as independent hands-on proficiency exams. These types of exams are expensive and with the frequency of ASVAB updates the composites will constantly require re-validation.

A. CONCLUSIONS

The continued use of the ASVAB is supported, as it is an appropriate battery to measure a youth's aptitude to successfully complete a Marine Corps course suited to that individual. The discriminant method shows that the ASVAB composites are placing individuals with similar aptitudes into courses requiring those types of individuals. There is a distinct clustering of like individuals into Marine Corps courses. The tree based method provides a means to show that further use the ASVAB composites could improve the overall job assignment process. By increasing entrance requirements for a course, the

tree based method illustrates that higher FCGs can on average be achieved. The larger issue is how much to increase the ASVAB selection requirements for each course and the effect these changes would have on Marine Corps job performance.

B. RECOMMENDATIONS FOR FURTHER STUDIES

If ASVAB composite scores used for selection into a course were raised by 5 or 10 points, an interesting study could estimate the impact on Marine Corps job performance. This potential topic would have to balance the relative move up of job performance and how that increase in job performance translates into improved Marine Corps effectiveness. Further consideration would need to include a look at the pool of eligible recruits in order to fill some of the more stringent MOSs.

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APPENDIX A. SELECTED MARINE CORPS COURSE LIST

CID	Course Title	FY 95 Plan
A010801	Small Arms Repair	346
A10RF31	Law Enforcement	865
A13TBM1	M1A1 Crewman	220
A141351	Petrol Supply Specialist	480
A1433L1	Food Service Specialist	941
A200811	Field Artillery Fire Controlman	254
A200821	Cannon Crewman	766
A2123C1	USA Ammo Specialist	289
F02CGQ1	ULCS Operator/Maintenance	200
F0764T2	Air Craft Fire Fighting Rescue	261
M02D3J1	Entry Level Small Computer Systems Specialist	325
M0301C8	Personnel Clerk	509
M0301S8	Unit Diary Clerk	473
M0301T8	Administrative Clerk	1015
M030314	Rifleman (Lejuene)	2154
M030334	Machine Gunner (Lejuene)	432
M030344	Mortarman (Lejuene)	560
M030354	Assaultman (Lejuene)	448
M031102	Basic Hygiene Equipment Operator	291
M0311B2	Basic Electrician	203
M031302	Basic Combat Engineer	1022
M0313B2	Basic Engineer Equipment Mechanic	417
M0313F2	Basic Engineer Equipment Operator	507
M0313I2	Basic Landing Support Specialist	302
M0330V1	Enlisted Supply Basic	990
M0333L6	Basic Food Service	1122
M0335H7	Automotive Organization Maintenance	955
M0335X7	Motor Vehicle Operator	2596
M0335Z7	Logistics Vehicle System Operator	550
M092471	Field Wireman	761
M092541	Communication Center Operator	440
M0925U1	Field Radio Operator	2450
M092721	Basic Electronics	1359
M0927M1	Ground Radio Repair	460
M0927V1	Radio Fundamentals	648
M09CGM1	Multi-Channel Equip Operator	400
M100312	Rifleman (Pendleton)	3661
M100332	Machine Gunner (Pendleton)	681
M100342	Mortarman (Pendleton)	630
M100352	Assaultman (Pendleton)	705
M10AHY3	Assault Amphibian Crewman	644
M10H2F2	LAV Crewman	315
M10T2B2	TOW Crewman	283
N246481	Aviation Support Equipment Tech	471
N2464A1	Aviation Machinist Mate	630
N2464H1	Aviation Structures Mechanic	332
N2464L1	Aviation Hydraulics Mechanic	321
N2465A1	Aviation Ordnanceman	579
N246601	Avionics Tech	1113
N246661	Aviation Electronic Mate	448
N2467V1	Basic Helicopter H-46	321
N24WPE1	Basic Helicopter H-1	256
N24WPF1	Basic Helicopter H-53	223
N3330B1	Aviation Supply Mechanized	431

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